

METHOD AND APPARATUS FOR PARTITIONING MEMORY IN A TELECOMMUNICATION DEVICE

FIELD OF THE INVENTION

[0001] The present invention is related generally to telecommunication and, more specifically, to a technique for partitioning memory to conserve power in telecommunication devices.

BACKGROUND OF THE INVENTION

[0002] Wireless telecommunication devices are evolving to contain increased functionality and complexity. This increased functionality often brings together functions that have been traditionally been provided by different devices such as cell phones and personal digital assistants (PDA). The combination of these functions typically require increased processor capability as well as increased power requirements. The requirement for additional processing capability to add functionality and minimize latency is especially important when the information must be processed in real time, as for example in cell phones. Having more processing capability and in turn higher power consumption, is especially problematic in wireless communication systems where it is inconvenient to connect to power sources.

[0003] Wireless communication systems generally must contain their own source of power, which often is in the form of a battery. Users typically need the ability to operate such systems for longer periods of time without the need to recharge or swap batteries or even connect to line power. However, such longer operating times normally require an increase in battery size, which leads to undesirable effects such as heavier batteries, increased expense, and environmental concerns regarding disposal of used batteries.

[0004] To meet the needs of increased processing power within wireless communication devices, additional processors requiring more memory and power were added to devices. A general purpose processor handles most system tasks and a modem computing subsystem handles tasks related to handling mobile station requirements. Mobile station modem binary software images (i.e., contents of memory) are programmed at the time of manufacture into read-only memory (ROM) as a single contiguous binary image. The modem computing subsystem directly executes the memory image from ROM, which results in slower execution than images executed from memories with faster access times, such as random access memory (RAM). At system boot time (e.g., when the wireless device is powered-up), read-write and zero-initialized data are copied to RAM prior to execution of code by the modem computing subsystem. No part of the over-the-air

standards as implemented in the software binary image can be executed prior to completion of system boot and initiation of the operating system. All system memory must be completely powered-up prior to mobile station modem operation of the over-the-air standard. This approach results in wasting significant amounts of power because the modem computer subsystem had to be powered up even when not in use.

[0005] Therefore, it can be appreciated that there is a significant need for a system and method to minimize power consumption in a wireless communication system while increasing the speed and functionality of the device for the user. The present invention provides this and other advantages that will be apparent from the following detailed description and accompanying figures.

SUMMARY OF THE INVENTION

[0006] The present invention is embodied in a method and apparatus for partitioning and downloading executable memory images in low-powered computing devices comprised of multiple processors and a mobile station modem. In one embodiment, the system comprises a communications-related personal digital assistant (PDA) that contains two computer subsystems. The general computing subsystem handles tasks generally related to a PDA as well as gating independently the clock that activates the modem computer subsystem and one or more shared memory modules. The modem computing subsystem handles tasks associated with a mobile station modem. The system is able to conserve power by not clocking the modem computer system and the shared memory during times when the modem function is not needed. The shared memory modules are loaded with a binary memory image for use by the modem computer subsystem from a nonvolatile memory by the general computing subsystem.

[0007] In another embodiment, the system boots the general computing subsystem, which contains a nonvolatile memory, boots the modem computing subsystem when it is desired to monitor a paging channel, and disables the modem computing system to conserve power when it is no longer desired to monitor the paging channel. This embodiment may enable the modem computing system by providing a clock to the first shared memory module, loading the shared memory module with a binary memory image based on information stored in the nonvolatile memory, providing a clock to activate the modem computing subsystem, and vectoring the processor so that it executes instructions from the binary memory image stored on the shared memory module. The modem computing subsystem may be deactivated to save power when the

modem function is not necessary. Additionally, a second shared memory may be activated and used only when the modem computing system needs to manage a traffic channel.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0008] FIG. 1 is a top-level block diagram of the present invention.
- [0009] FIG. 2 is a functional block diagram of exemplary interfaces of the present invention.
- [0010] FIG. 3 is a detailed functional block diagram of the system.
- [0011] FIG. 4 is a flow chart illustrating an example of the processing steps of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

- [0012] The present invention permits the independent activation and deactivation of portions of a low-powered telecommunication and computing device that are only required in the course of transmitting and receiving data. In an exemplary embodiment, the present invention is implemented using a wireless modem station operating in conjunction with a personal digital assistant (PDA). The combination device may be referred to as a mobile unit, cellular telephone, communicator, or the like. As will be discussed in greater detail below, the present invention is not limited to a specific form of mobile communication device, nor is it limited to a particular over-the-air standard.

- [0013] The present invention is embodied in a system **100**, which is illustrated in the block diagram of FIG. 1. The system **100** includes a general computing subsystem **102** and a modem computing subsystem **104**, which will be described in greater detail below.

- [0014] The general computing subsystem **102** provides control lines **106** that are used to activate, synchronize, and deactivate the modem computing subsystem **104**. Both the general computing subsystem **102** and the modem computing subsystem **104** may alternately assert or remove a clock signal to a shared memory modules Bank I **108** and Bank II **110** in the course of activating modem functions. The shared memory modules **108-110** are loaded by the general computing subsystem **102** and contain an executable binary memory image for use by the modem computing subsystem **104**. The executable binary memory image comprises instructions and data that the processor of the modem computing subsystem **104** will execute and manipulate. A bus **112** is used to load and access the shared memory module **108**, and a bus **114** is used to load and access the shared memory module **110**. The general computing subsystem **102** generates clock signals BNK I CLK **116** and BNK II CLK **118**, respectively to control the operation of the memory

modules **108-110**, respectively. Similarly, the modem computing subsystem **104** generates clock signals BNK I CLK **120** and BNK II CLK **122** to control operation of the memory modules **108-110**, respectively. The operation of the clock signals **116-122** to control the memory modules **108-110** is discussed in greater detail below.

[0015] FIG. 2 is a functional block diagram of exemplary interfaces of the present invention. It will be apparent to one skilled in the art that each of the interfaces of system **100** may be directed to the general computing subsystem **102** and the modem computing subsystem **104** either operating together or alone depending on how the functionality of each the interface is used and when the functionality is needed. In one embodiment interfaces that are needed to operate the PDA in general are classified as a PDA peripherals **220** and interfaces that are only needed during operation of the modem computing subsystem **104** are classified as modem peripherals **244**.

[0016] The system **100**, which typically embodies the functions of both a computing device, such as a PDA and a wireless communicator, includes a transceiver and antenna **128** to allow transmission and reception of data, such as audio communications, between the system **100** and a remote location, such as a cell site controller (not shown). The remote location may host data and communications services such as voice, data, email and internet connections. The operation of the wireless voice and data communications is well known in the art and need not be described herein except as it relates specifically to the present invention.

[0017] Preferably, system **100** comprises a power management device **130** that comprises a rechargeable battery and that provides a power supply. System **100** operates in different operational modes with each operational mode having a different level of power consumption, including "Fully Active" wherein the PDA is active and a voice call is in progress, "PDA Active" wherein the PDA is active and the modem and modem functions are asleep, "Phone Active" wherein the PDA is asleep and a voice call is in progress, "Sleep" wherein the PDA is asleep, no voice call, and slotted paging mode is active, and "Deep Sleep" wherein the PDA is asleep and the phone is off. Those skilled in the art will appreciate that a "voice" call can comprehend the functionality of an active traffic channel (including data traffic), and that in the slotted paging mode the modem processor periodically listens to transmissions from a base station to determine if there is an incoming call. It can be readily seen that other combinations of functionality and power consumption are possible. The power management device **130** also may include a sleep timer to awaken the system **100** after a predefined time interval.

[0018] The system comprises human interfaces for providing information to and receiving information from users. Visual indicators such as a serial liquid crystal display (LCD) **132**, a

color liquid crystal display **134**, and light-emitting diodes (not shown) are used to rapidly convey information to the user. Tactile receptors such as a touch screen **130** and keypad **138** allow the user to enter data and commands and to manually respond to system queries. It is apparent to those skilled in the art that other display types and input devices may be used acceptably. Audio input and output, provided by headset/mic **140** and stereo digital-to-analog converter (DAC) **142**, allow for two-way communication, as well as command input by using voice recognition, and aural responses to user input. Ideally, the human interfaces and physical system design will be presented in a pleasing and ergonomic fashion so as to provide for ease-of-use of the device.

[0019] Interfaces are provided to allow for expandability, such as a multimedia card (MMC) slot **144**, and one or more memory expansion slots **146**. Communication between the system **100** and other computers or devices can be accomplished via a serial port **150**, which is preferably a universal serial bus (USB) transceiver. JTAG-type (Joint Test Action Group) boundary scan testing may also be provided.

[0020] FIG. 3 is a detailed functional block diagram according to the invention. The general computing subsystem **102** and the modem computing subsystem **104** are controlled by a general system microprocessor **202** and a modem subsystem processor **204**, respectively. Those skilled in the art will appreciate that the term "processor" is intended to encompass any processing device, alone or in combination with other devices, that is capable of operating the telecommunication system. This includes microprocessors, embedded controllers, application specific integrated circuits (ASICs), digital signal processors (DSPs), state machines, dedicated discrete hardware, and the like. The present invention is not limited by the specific hardware component selected to implement the processors **202** and **204**.

[0021] The general computing subsystem **102** comprises a power management unit (PMU) **205** that receives as an input an external reset signal. This signal may be derived from a power-up circuit, an external reset button, or a sleep timer. The PMU **205** provides a clock to the general subsystem processor **102** as well as bank arbitration blocks **206** and **208** of the shared memory modules **108** and **110**, respectively. The PMU **205** may be programmed by and provide status data to the general computing subsystem processor **202** via a general computing subsystem bus **209**.

[0022] Subsystem bus **209** may include a power bus, a control signal bus, and a status signal bus in addition to a data bus. However, for the sake of clarity the various buses are illustrated in FIG. 3 as the subsystem bus **209**. The subsystem bus **209** allows the general computing subsystem processor **202** to receive and send data to nonvolatile memory **222** and static RAM (SRAM) **224**,

to control registers **216**, to the shared memory modules Bank I **108** and Bank II **110**, and to PDA peripherals **220**. A busmaster **211** provides additional logic for bus interface control logic as well as electrical buffering of signals on subsystem bus **209**.

[0023] To conserve power and offload processing requirements of the general computing subsystem processor **202**, a DMA (direct memory access) channel is provided to transfer data without processor intervention. DMA technology is well known in the art and need not be discussed here. A DMA/microprocessor memory interface **210**, DRAM controller **212**, and MMC DMA Controller **214** are provided to allow direct memory access of the shared memory modules **108** and **110** by the general subsystem processor **202** and the PDA peripherals **220** via the memory interface bridge **218**. The MMC DMA Controller **214** may be configured as the DMA master and the DRAM controller **212** and MMC DMA Controller **214** are configured as slaves.

[0024] The DMA/microprocessor memory interface **210** also serves to allow proper access to the nonvolatile memory **222** and SRAM **224** by the general computing subsystem processor **102**. In typical embodiments nonvolatile memory **222** is a memory such as flash ram that is preprogrammed with boot code, operating instructions, and data for both the general computing subsystem processor **202** and the modem computing subsystem processor **204**. A portion of the memory contents of nonvolatile memory **222** may optionally be stored and accessed according to well known data compression techniques for the purpose of reducing the amount of nonvolatile memory required. The data and instructions required for the operation of the modem computing subsystem processor **204** are copied from nonvolatile memory **222** and stored in SRAM **224**, which has lower access times than that of a nonvolatile memory thus permitting faster execution by the modem computing subsystem processor **204**.

[0025] The modem computing subsystem **104** comprises a clock/power control unit **230** that provides clocks **120-122** to the bank arbitration blocks **206** and **208** of the shared memory modules **108-110**, respectively, and provides a clock **250** and a reset line **252** to the modem subsystem processor **204**. The clock/power control unit **230** is used to conserve power by gating (i.e., shutting off) the clock **250** to the modem subsystem processor **204** and the clocks **116 - 122** to the shared memory modules **108-110**, respectively, during times when these modules are not needed for operation of the modem portion of the system **100**.

[0026] When the modem system processor **204** is needed in one embodiment, clock **250** will be applied to the modem subsystem processor **204**, and clock **116** from the general computing

subsystem **102** is applied so that the Bank I shared memory module **110** may be loaded by the general computing subsystem **102**. The clock **116** is maintained so as to allow the data stored in the module **110** to be refreshed. The modem computing subsystem **104** may access the module **110** by asserting clock **120**. The modem computing subsystem **104** may access the Bank II shared memory module **112** by asserting clock **122**, which may be used to keep the data stored in module **112** refreshed after the data is stored therein by the general modem computing subsystem **102**. The general modem computing subsystem **102** may access the module **112** by asserting clock **118**.

[0027] The general computing subsystem **102** uses the control registers **216** to signal a clock/power control unit **230** to supply the clocks **120-122** to the shared memory module **108** so that the boot code for modem computing subsystem **104** may be stored and retained in the shared memory module **108**. The control registers **216** also are used to reset and start the modem computing subsystem processor **204**, which will then access the boot code in the shared memory module **108**.

[0028] In one embodiment, the modem subsystem processor **204** communicates with the general computing subsystem processor **202** via shared memory modules **108-110** by using locations in memory to store information about the status and mode of operation of the modem computing subsystem **104**. The general computing subsystem processor **102** polls the status information and signals the clock/power control unit **230** to assert and remove the clocks **120-122**, as well as to load portions of the shared memory modules **108-110**. Alternatively, the modem subsystem processor **204** may signal the general computing subsystem processor **202** using, by way of example, a vectored interrupt method to instruct the general computing subsystem processor **202** to, for example, load a portion of the shared memory modules **108-110**.

[0029] A subsystem bus **240** allows the modem computing subsystem processor **204** to receive and send data to control registers **242**, to the shared memory modules **108-110**, and to modem peripherals **244**. The subsystem bus **240** may include a power bus, a control signal bus, and a status signal bus in addition to a data bus. However, for the sake of clarity the various buses as the subsystem bus **240**. A busmaster **246** provides additional logic for bus interface control logic as well as electrical buffering of signals on subsystem bus **240**.

[0030] To conserve power and offload processing requirements of the modem computing subsystem processor **204**, a DMA channel is provided to transfer data without processor intervention. A DMA/microprocessor memory interface **260** is provided to allow direct memory

access of the shared memory modules **108-110** by the modem subsystem processor **204** and the modem peripherals **244** via a memory interface bridge **262**.

[0031] The modem computing subsystem **104** uses the control registers **242** to signal the clock/power control unit **230** to supply clock pulses via clock **120** to the shared memory module **110** so that the modem operational software image for modem computing subsystem **104** may be stored and retained in the shared memory module **110**. This will typically occur prior to the modem computing subsystem **104** leaving the slotted paging mode and entering the traffic mode. The control registers **216** also are used to signal the clock/power control unit **230** via signal **226** to remove the clock **122** from the shared memory module **110** when the modem computing subsystem **300** reverts to the slotted paging mode from the traffic mode.

[0032] The shared memory modules **108-110** each comprise one or more dynamic RAMS **280** and **282**, respectively, so that power is conserved when the memory is not clocked. As an additional benefit, the cost of the DRAM is less than that required for static RAM. The shared module **108** is used for storing the boot code of the modem subsystem processor **204** and the software necessary for operating the modem computing subsystem **104** when the wireless device is operating in the slotted paging mode. The shared memory module **110** is used for storing the software necessary for operating the modem computing subsystem **104** when the wireless device is operating in the traffic mode. It will be apparent to those skilled in the art that other shared memory modules may be used to further partition the memory image so that the additional memory banks need only be activated during certain modes that would be associated with the code stored in the additional banks.

[0033] The bank arbitration blocks **206** and **208** each receive clocks (i.e., the clocks **116-122**) from the general computing subsystem **102** and the modem computing subsystem **104** because the subsystem processors (i.e., the general subsystem processor **202** and the modem subsystem processor **204**) are not necessarily synchronized, the bank arbitration blocks **206-208** must be capable of handling the protocols of memory requests from systems having unrelated clocks. The arbitration blocks **206** and **208** each must not only handle unrelated clocks, but also be capable of handling simultaneous and nearly simultaneous requests from both subsystems. The arbitration blocks **206** and **208** receive the requests via the memory interface bridges **218** and **262**, resolve any contention between the subsystems, synchronize the local clocks to the subsystem having priority, and respond via the appropriate memory interface bridge to the subsystem having priority. Such arbitration techniques are well known in the art and need not be described in greater detail herein.

[0034] FIG. 4 is a flowchart illustrating the operation of a low-powered telecommunication and computing device according to the present invention. These steps are performed by the device as it is powered up and enters various modes.

[0035] Specifically, in step **300**, a general computing subsystem reset occurs either upon applying power to the system **100**, or at anytime when requested. The general computing subsystem reset may be applied during any step described herein, although this capability has been omitted from the flowchart of FIG. 4 for the sake of clarity. After reset, the general computing subsystem **102** boots in step **3j02**. To conserve power, in step **304** all unnecessary clocks are disabled, including the clocks (e.g., the clocks **120-122** and the clock **250**) in the modem computing subsystem **104**. The modem computing subsystem **104** is placed in a reset mode in step **306**.

[0036] In step **308**, the general computing subsystem **102** applies a clock (i.e., the clock **118**) to shared memory module **110**. A software memory image necessary for the operation of the modem computing subsystem **104** to boot and enter and maintain the slotted paging mode is loaded into the shared memory module **108** in step **310**. The modem computing subsystem **104** is released from reset in step **312**, and then boots in step **314** using instructions and data from the memory image stored in the shared memory module **108**. The modem computing subsystem **104** enters the slotted paging mode in step **316** and monitors the paging channel until, in decision **318**, a request for traffic is detected (for incoming requests) or posted (for outgoing requests).

[0037] Upon such a request, in step **320**, the general computing subsystem **102** applies the clock **116** to the shared memory module **110**. A software memory image necessary for the modem computing subsystem **104** to operate a traffic channel for voice, data, or SMS is loaded into the shared memory module **110** in step **322**. When the memory image is loaded, in step **324** the modem subsystem processor **204** accesses the contents of the shared memory module **110** for code and data necessary to facilitate a traffic channel. In decision **326**, the modem subsystem processor **204** determines whether traffic is present and, if so continues in step **324**, else continues on to step **328**, where the clocks to the shared memory module **110** are removed and the modem computing subsystem **104** then returns to step **316** where the slotted paging mode is again reentered. Thus, the system **100** provides increased computing and data processing capability while controlling circuitry to reduce power consumption.

[0038] It is to be understood that even though various embodiments and advantages of the present invention have been set forth in the foregoing description, the above disclosure is illustrative only, and changes may be made in detail, yet remain within the broad principles of the invention. Therefore, the present invention is to be limited only by the appended claims.